The Solar System,

ILLUSTRATED

BY THE

GEOSELENEAN.

BY JOHN G. MOORE, M. S.

Teacher and Lecturer in Friends' Central High School.

PHILADELPHIA, Pa.

MANUFACTURED & FOR SALE BY

CHARLES A. SAXE,

No. 39 South 10th St.,

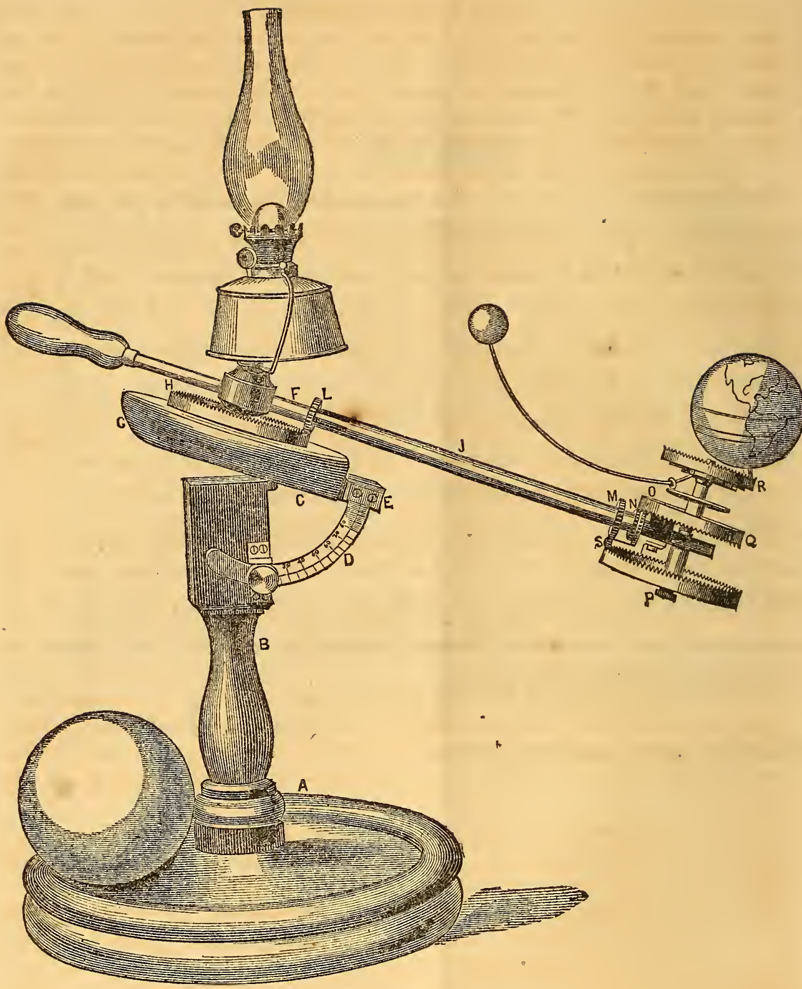
PHILADELPHIA, Pa.

PREFACE.

In the present age, the use of demonstrative apparatus is generally appreciated by educators. It is conceded that truths and principles when illustrated make a more vivid and lasting impression on the mind. This is particularly the case in teaching the science of Astronomy. Tellurians, planetariums, etc., serve a very useful purpose in this respect, but there are many combined motions and phenomena of the Solar System which cannot be satisfactorily represented by them. A necessity, therefore, seemed to exist for a more complete and comprehensive astronomical instrument. To supply this deficiency, the Geoselenean was invented. Since its first construction, however, its frequent use in the school room has suggested numerous improvements. As many as practicable of these have been added; and in its present form, it is offered to the consideration of those interested in the science with the sincere hope of the inventor, that it may prove a valuable auxiliary in teaching.

John G. Moore.

Philadelphia, November 21st, 1865.



CONSTRUCTION.

The Geoselenean is represented in the cut. It consists of a base A into which is screwed the upright post B supporting the table G upon which the crown-wheel H is permanently attached. From the centre of H extends an upright pin whose lower part serves as an axis for the shaft F, and the upper part retains the lamp in position or answers for the sun's axis.

Rotating upon the central pin under the pressure of the hand is the shaft F, near whose outer end is an upright shaft on which the various horizontally moving wheels with one exception are journaled directly or indirectly, and on which is attached the elbow designed for the axis of the planet. As the said upright shaft is rotated by the gear-wheel P which engages by means of an intermediate pinion S with the wheel M near the outer end of the sleeve J whose inner end carries a toothed wheel which

meshes into the crown wheel H before mentioned. It will be seen that the rotation of the shaft F upon its axis, rotates the sleeve J upon the shaft F by the engagement of the wheel L with the crown wheel H and the wheel M communicates revolution to the crown-wheel P through the, pinion S rotating the vertical shaft in such a manner that although it revolves. yet it retains nearly the same direction in reference to a given line in space

The object of this arrangement is to give the true position of the earth's axis and to show not only day, night, the seasons, etc; but also the recession of the equinoxes and its effects. The number of the teeth of the wheel P is proportioned relatively to those of the wheels which actuate it, and for instruments of moderate size the wheels L and M may have one-fourth as many teeth as H has, while P has one tooth less than H, to obtain a slow rotation of the wheel P relatively to the sun. The small wheel S aids in obtaining this result by reversing the direction of the rotation of the wheel P.

At the outer end of the sleeve J beyond the wheel M formerly mentioned are two wheels N and O, the former of which gears into the spur-wheel Q, which rotates upon and independently of the inner sleeve to which the moon-carrier is attached. On the outer sleeve there is an oblique circular plane forming a track for the roller of the moon-carrier. The revolution of the wheel Q with the oblique plane preserves the moon's orbit in its true position in reference to the orbit of the earth. The proportion of the number of teeth in the wheels N and Q is such that Q makes about one-eighteenth of a revolution in the period of a year and thus shows the recession of the moon's nodes and regulates the phenomena of solar and lunar eclipses.

The crown-wheel R is attached to the upper end of an inner sleeve and is revolved with it by means of the gear-wheel O, on the end of the sleeve J which wheel meshes into a horizontal wheel and this again into a pinion on the inner sleeve. These two wheels are under the wheel Q and are concealed.

The wheel R rotates about twelve times while the whole revolving system completes one revolution. It carries the moon around the earth and at the same time rotates the earth upon its axis by means of the engagement of the pinion on the earth's axis with the teeth of the wheel R. The object of the intermediate wheel beneath Q is to reverse the motion so as to revolve the moon and rotate the earth from west to east while the annual motion is from west to east. These motions are obtained by giving the pinion one-third as many teeth as O and the middle wheel as many as O.

The table G may be inclined at pleasure being hinged to the standard at C, the graduated arc D indicates the angle.

There are three elbows with corresponding inclinations to the axes of the earth, Jupiter, and Venus to the planes of their respective orbits. These are attached by means of a screw upon the shaft in the centre of the wheel R, and can be changed at pleasure. The three extra moons are to be inserted beneath the wheel R, to illustrate the satellites of Jupiter. Saturn has his rings and satellites adjusted. The zenith director consists of an upright rod designed to be inserted into an aperture in the earth at the latitude of the place in which the instrument is to be used. The angle measurer is a rod with a graduated arc attached, to be used in connection with the zenith wire for determining the altitude of the sun, moon, etc.

GEOSELENEAN.

The Geoselenean is designed to illustrate the principal motions and phenomena of the Solar System. The name is derived from two Greek words, Ge, the earth, and Seléne, the moon—relating to the earth and moon. As the apparatus exhibits the phenomena of the other planets and their satellites, the name is not sufficiently comprehensive to indicate its full application; it expresses, however, all for which the instrument was originally designed.

GENERAL REMARKS.

Adjustment of the Elbows.—Revolve the shaft to June 21st, as marked upon the zodiac; place the elbow of the planet with the angle from the sun, so that the side by which it is attached, will extend in the direction of the shaft; and the other side which is designed for the axis of the planet, will be at its greatest distance from the sun.

How the motion must be given. — The only manipulation necessary to give motion to the various parts of the geoselenean is the revolution of the main shaft. The force must be applied in the same plane in which the arm revolves; and, in *such a manner that the motion of the shaft will be in a reverse direction to the hands of a watch.* This simple circular rotation causes the combination of all the movements which represent the principal positions and motions of the earth and moon, or of any planet and its system.

CHAPTER I.

THE EARTH.

Motions of the Earth.—Adjust the elbow whose angle is 66½°; place the earth upon the pin designed for its axis; give motion to the apparatus, and observe that the earth not only revolves upon its own axis, but also that the motion is from west to east as the eastern part of any country is exposed to the sun before the western portion.

The same movement which produces the diurnal motion causes simultaneously the annual revolution of the earth. This is also from west to east as a little more than a complete revolution of the earth upon its axis, is necessary to bring a given meridian under the sun, and as those parts of the earth which are most distant from the sun, are carried by both motions in the same direction. It may also be shown in this connection that east and west are only relative terms—that the absolute direction of the daily motion is just opposite every twelve hours; and, of the yearly every six months.

The Plane of the Ecliptic — Inclination of the Earth's Axis. — The plane of the ecliptic extends through the centres of the earth and sun, and may be indicated as the earth revolves. The shaft in a revolution, describes a plane parallel to it. The earth's axis is permanently inclined at an angle of about 66½°, and the equinoctial at an angle of about 23½° to the plane of the ecliptic.

The geoselenean is so constructed that the phenomena of the earth may be elucidated either when the plane is horizontal or inclined. In the former position, the axis of the ecliptic is directed toward the zenith. The main facts to be explained may be exhibited while the shaft occupies this position, but not to the best advantage. The ecliptic plane may be inclined at any angle, but there are two positions preferable to others; first, when

the earth's axis is directed toward the zenith; and secondly, when it extends toward the north star. To illustrate the former, incline the shaft 23½° from a horizontal plane and consider the zenith as the north star toward which the axis then tends. An annual revolution of the earth now shows very clearly the oscillations of the equinoctial; that at the equinoxes it is directed through the centre of the sun; at the winter solstice it extends above, and at the summer solstice, below the sun — that it is continually changing yet remaining parallel to the same plane. The second inclined position is obtained by diverging the main arm 73½° or till the earth's axis is directed toward the north star. The ecliptic of the instrument will then be parallel to the natural ecliptic, and will well represent its direction in the heavens. The earth, too, can be brought to its exact position in its orbit by observing the months upon the zodiac; when its motions and positions, the direction of the zenith in any latitude and for any hour of the day will be faithfully represented. This arrangement elucidates the various phenomena to the best advantage as the positions as well as the facts are illustrated. It, however, requires more care in giving the motion—that it does not become too rapid. In the following explanations some special positions of the plane of the ecliptic will be chosen, it being now understood, that the one selected may be used, or any other at the pleasure of the operator.

Parallelism of the earth's axis.—Direct the axis of the earth toward the zenith, cause the earth to complete several annual revolutions; and observe that the axis continues in about the same general direction or retains a parallelism to a given line in space. When the number of revolutions exceeds ten, the fact becomes apparent that the direction of the axis is not absolute, but that it is slowly and gradually changing. For all illustrations the recession of the equinoxes excepted, when this change becomes too great, the operator should unscrew the axis and place it again in its first position. Ordinarily, this will not be necessary during a lesson or lecture as the number of revolutions which can be made without a sensible variation in the direction of the axis, is sufficiently great to illustrate one and even several facts.

Altitude of the ecliptic — Zenith distance and declination of the sun.–The ecliptic plane appears to occupy different positions in the heavens. This is caused by its inclination to the equinoctial together with the annual and diurnal revolutions of the earth. The axis of the earth being inclined to the ecliptic plane at an angle of 66½°, forms with a line moved in this plane, angles varying from 66½° to 113½°; hence, the meridian altitude of the ecliptic in a daily revolution of the earth, varies about 47°. It must be remembered, also, that a perpendicular to the earth's surface at latitude 40° forms with its axis an angle of 50°, which being deducted from the above angles will give respectively the least and greatest zenith distance of the sun. For convenience the following table has been arranged showing for latitude 40° about the zenith distance, altitude, and declination of the sun at the times designated.

TIME.		ZENITH DISTANCE.	ALTITUDE.	DECLINATION.
MARCH	21st,	40°	50°	00
APRIL	21st,	28°	62°	12° North.
MAY	20th,	20°	70°	20 "
JUNE	21st,	16½°	73½°	23½° "
JULY	18th,	19°	71°	21° "
AUGUST	21st,	28°	62°	12° "
SEPTEMBER	21st,	40°	50°	00
OCTOBER	20th,	50°	40°	10° South.
NOVEMBER	21st,	60°	30°	20° "
DECEMBER	21st,	63½°	26½°	23½° "
JANUARY	21st,	60°	30°	20° "
FEBRUARY	20th,	50°	40°	10° "

To measure these distances; place the zenith director on the earth at latitude 40°, then insert the end of the angle measurer into the small hole in the base of the zenith wire, and hold the other end so that the line will be in a plane parallel to the ecliptic. The graduated arc will indicate the zenith distance of the sun, the complement of which will be its altitude. The declination of the sun is its distance north or south of the equinoctial, hence when the sun is north its declination is ascertained by deducting the zenith distance from 40°; when south, by taking the latter quantity from the former.

The plane of the ecliptic may be located by a process similar to the following: bring the earth to June 21st; apply the measurer which indicates at midday that the sun's zenith distance is about 16½°. Cause now the earth to revolve slowly upon its axis, and carry the angle measurer around in the plane of the ecliptic; observe that the angle increases until half a revolution is described when it is about 63½°, and diminished during the other half till it attains about its former quantity. The sun's zenith distance at the winter solstice during midday is about 63½°, while at midnight that of the ecliptic is but 16½°. In this way, the altitude of the ecliptic may be determined for any hour of the day, or any day of the year. For other latitudes, the only change necessary is the location of the zenith wire. A corresponding table can easily be formed.

Zodiacal Signs.—The signs of the zodiac are represented on the table supporting the sun. The earth is in that sign nearest to it; while the sun is in the one on the opposite side of the sun from the earth. That is if the earth is in Aries, the sun is in Libra; or if the earth is in Taurus, the sun is in Scorpio, etc. The months are marked and indicate the time of the year when the earth and sun are in particular signs. The solstitial and the equinoctial points are printed upon the same plane; and it can, therefore, be easily determined when the earth occupies any of these important positions.

Changes of the Seasons.—The changes of the seasons result from the inclination of the ecliptic to the equinoctial; the parallelism of the earth's axis; and the fact that only one half of the earth is illuminated at one time. To illustrate this and unequal day and night; incline the shaft 23½°; direct the earth's axis toward the zenith; light the lamp; darken the room; and revolve the earth. A single annual revolution exhibits the fact that the illuminated portion of the earth changes with its position in its orbit. When the earth is at either equinox, it is illuminated from pole to pole; when at the summer solstice its axis is inclined toward the

sun's rays exposing the north pole; and at the winter solstice the south pole is more toward the sun.

Day and Night— Cause of their inequality.—At the vernal equinox, March 21st, that hemisphere of the earth is illuminated from pole to pole and 180° in longitude; and as the earth revolves uniformly upon its axis, every part of its surface is half the period of one revolution in the light and the other half in darkness; therefore, over the whole globe, the days and nights are equal. Observe as the earth moves from the vernal equinox toward the summer solstice, that the circle of illumination changes both in latitude and longitude, and gradually extends beyond the north pole till the earth reaches the summer solstitial point, June 21st, when the light is limited by the Arctic circle $23\frac{1}{2}°$ beyond the north pole. The whole of the north frigid zone is then illuminated and the days there exceed 24 hours in length. At the pole the day will be six months long, because no diurnal revolution brings this pole beyond the circle of illumination while the earth passes from the vernal to the autumnal equinox. In the southern hemisphere, winter reigns as the sun's rays fall most obliquely. In this region the day corresponds in length to the night and the night, to the day of the northern hemisphere. The sun, at this point, is at its greatest northern declination, and its rays fall perpendicularly to the earth's surface at the tropic of Cancer. As the earth departs from this solstice toward the autumnal equinox, the circle of illumination so changes as to shorten the day and lengthen the night in the northern hemisphere, and produces the opposite effect in the southern. When this equinox is reached by the earth, the days and the nights are again equal in length. The revolution of the earth from this point causes the circle of illuminato gradually extend beyond the south pole till the whole south frigid zone is enlightened, producing in that region day; while the duration of our day is diminished, and our nights increased. The long night then prevails in the north frigid zone varying from 24 hours to six months. As the earth moves forward from the winter solstice and approaches the vernal equinox, the difference between the length of the days and nights becomes less and less, and entirely ceases to exist when the vernal equinox is reached.

Length of the Day.— The length of the day in any latitude may be easily ascertained by observing the number of degrees of longitude illuminated and making a calculation similar to the following. In latitude 40°, 200° of longitude are illuminated, April 20th.; the length of the day then must be $\frac{200}{360}$ or $\frac{5}{9}$ of 24 hours which equals 13 hours and 20 minutes. In latitude 75°, 300° of longitude may be illuminated, hence $\frac{300}{360}$ or $\frac{5}{6}$ of 24 hours, which equals 20 hours, the length of the day, etc.

Effect of a perpendicular axis.—To show the effect if the earth's axis were not inclined; remove the elbow and place in its stead, the accompanying one designed for Jupiter; have the shaft horizontal, and observe that during a revolution no change of the seasons would occur, and the days and nights would be equal throughout the year. Showing in this way how different conditions affect a phenomenon, frequently renders clearer those things essential to produce it.

The Earth's orbit Elliptical.—An ellipse is a plain curve, in which the sum of the distances of each point from two fixed points called the foci is equal to a given line. Perceive that the distance between the earth and the sun is greater during our summer than winter, or that the earth

is in its aphelion in summer and in its perihelion in winter. By measurement, it is determined that the change of distance from one solstice to the other is gradual. Do not fail to notice that the portion of the orbit traversed by the earth from the autumnal to the vernal equinox is shorter than from the vernal to the autumnal. The true figure which the earth describes in the geoselenean is an epicycle. The cycle is the point of attachment of the earth's axis and is equally distant from the axis about which the shaft revolves; it moves, therefore, in a circle; the earth in an annual revolution, its elbow remaining in one general direction, moves around this central point completing the epicycle. It may then be used to illustrate the cycle and the epicycle so generally resorted to in explanation of the irregularity of the motions of the planets in the Ptolemaic Theory and also in the Copernican prior to the discovery of the laws of planetary motion by Kepler.

Sidereal & Solar Day.—A sidereal day is the time elapsing from the transit of a star, to the transit of the same star again across the meridian. A solar day is the period intervening between two successive transits of the sun across the meridian. As the earth revolves around the sun, the solar day is about 4 minutes longer than the sidereal. Suppose a star in a position beyond the sun so that a transit of the sun and star may take place at the same time; revolve the earth till the star crosses the meridian which denotes a sidereal day; then revolve it a little farther, till the sun is on the meridian which measures the solar day. The small amount gained equals one whole day in a year; and hence 366 revolutions of the earth upon its axis are necessary to produce 365 days. Sidereal and solar time coincide at the vernal equinox, and from the explanation just given, it will be inferred that the gain in three months is 6 hours, in six months 12 hours, etc.

Recession of the Equinoctial Points. — The earth is in its equinoctial points when the plane of the equinoctial extends through the centre of the sun. The parts of the earth's orbit are marked by stars. They do not occur, however, in the same points on the ecliptic, but are gradually receding by a slow movement westward completing an entire revolution in 25,868 years. The most direct effect of this is the revolution of the pole of the earth about the pole of the ecliptic. This interesting phenomenon may be thus illustrated: direct the earth's axis toward the zenith; observe the exact position of the vernal equinox, and revolve the earth. The change will scarcely be perceptible until eight or ten revolutions have been made. It then becomes apparent that the earth's axis is changing a little in direction, and that the equinoctial points are receding. In 20 revolutions it will become very evident, in 30, the vernal equinox falls back to the place of the winter solstice; in 60, to the autumnal equinox when the axis of the earth will be inclined to its first position at an angle of 47°. This represents in nature 12,934 years. When 120 revolutions have been made, the vernal equinox has traversed the whole ecliptic and reaches again the starting point while the axis has made a complete revolution about the pole of the ecliptic, it has retained during this long period about the same inclination to the axis of the ecliptic. It has been directed to different stars, whose elevation above the horizon has been, in this latitude, the same as the north pole star, because the altitude of the north star is always equal to the latitude of the place of observation. The equinox occurs March 21st, and as it recedes to avoid the disarrangement of the months, etc., it is necessary to place the extra zodiac loosely over the

permanent one, so that it can be moved around as fast as the equinoctial point recedes. This will indicate, too, how the present signs of the zodiac differ from the constellations bearing the same names. They doubtless corresponded when first named.

The cause of Recession.—The cause of the recession of the equinoxes is ascribed to the oblique attraction of the sun and moon upon the protuberant mass of matter about the equatorial regions of the earth. To represent this excess of matter, surround the equator of the earth with the plain band of paper. In accordance with the action of gravity that part of a body containing the greatest quantity of matter is directed towards the attracting body. A sphere of unequal density comes to rest with the heaviest portion towards the earth. As this is a very important experiment for the illustration of the phenomenon of recession as well as others in astronomy, the ball used to represent the sun has been made heavier upon one side and only comes to rest when free to move with that side downward. Observe when the earth is at either equinox this mass of matter is toward the sun and there is then no tendency to deflection as the excess of matter is then directly and equally attracted like the sphere at rest. As soon as the earth departs toward either solstice, this bulged mass becomes inclined to the line of attractive force of the sun and moon. It reaches at the solstice the inclination 23½° when the amount of deflective force is greatest. The force of attraction of the sun tends to draw this ring of matter to the plane of the ecliptic as the earth does the sphere when the heaviest part is upon one side. This would be the inevitable result if the force acted alone, but as it operates in conjunction with the rotary motion of the earth from west to east, the protuberant mass moves in obedience to the law of resultant motion and is twisted from east to west intersecting the ecliptic at each revolution farther westward.

It will be readily seen as celestial longitude is reckoned eastward from the vernal equinox, the recession will cause an augmentation of the longitude of celestial bodies, and, therefore, it is necessary that the error should be rectified every few years.

The Tropical year.—The tropical year is the time employed by the earth in revolving from the vernal equinox to the vernal equinox again; as this point is receding it does not require an entire circuit of the earth's orbit. The tropical year is, therefore, the amount of recession shorter than the sidereal year which is measured by a star.

CHAPTER II.

THE MOON.

This beautiful orb is a constant attendant of the earth in its circuit about the sun. It is an opaque body becoming visible to us only by reflected light. The phenomena of the moon illustrated by the geoselenean appear to the best advantage when the lamp is used for the sun, and the experiments conducted in a dark room. It must be remembered that the position of the observer is supposed to be on the globe representing the earth, as the phenomena appear differently when viewed from other locations. It is well for the operator to change the position of the instrument so that the relative position of the sun, earth, and moon may present the same appearance as they do from the earth. It is *very essential* in the illustration of the *moon's altitude and eclipses* that the *centre* of the moon when she is in *conjunction* and at her *node, should* be in a

straight line with the centre of the sun and earth. The adjustment is easily made by bending the wire carrying the moon.

Motion of the Moon from west to east.—Observe when motion is given to the instrument that the moon accompanies the earth in its annual journey; revolves about it twelve times in a year, and that her motion is from west to east.

A Synodic Revolution of the Moon.—A synodic revolution of the moon is the time employed by her in passing from one conjunction to the same conjunction again; this period is longer than the sidereal month. The difference is caused by the motion of the earth about the sun.

Orbit of the Moon.—In reference to the earth the orbit of the moon is an ellipse. Measure the distance of the moon from the earth at several points during a revolution, when it will be ascertained that she is in her perigee when nearest, and apogee when farthest away. The moon's motion combined with the earth's causes the former to produce an irregular curve which should, however, be concave toward the sun.

The instrument fails to exhibit this motion correctly. The defect arises from the great comparative distance of the moon. She never retrogrades in her orbit. She only could were her distance from the earth very much greater. This can be shown.

Plane of the Moon's orbit—Its inclination to the Ecliptic.—The plane of the moon's orbit is inclined to the ecliptic at an angle of $5\frac{1}{8}°$. This is represented by the inclination of the circular plane which forms a track for the moon-roller. The plane of the orbit, however, is parallel to this, and passes through the centres of the earth and moon.

Moon's Phases.—About one half of the moon's surface is illuminated at one time. If this enlightened hemisphere is turned towards the earth, the moon is full; if it is turned from the earth, the moon is invisible. Whatever portion of the illumined side may be toward the earth may be seen. As the relative positions of the earth, sun, and moon are not always the same, those appearances of the moon arise which are called phases.

New Moon—First Quarter.—At the dark of the moon, the centres of the sun, earth, and moon are nearly in the same straight line, the moon being the middle body, and in conjunction. At this point, the illuminated surface of the moon is turned from the earth, and therefore cannot be seen. As soon as the moon moves a few degrees eastward of this point, a small portion of her illuminated hemisphere appears in a crescent form; and, when one fourth of a lunar revolution has been made, the moon being upon the meridian at sunset, about one half of her enlightened surface is exposed to the earth.

Full Moon—Third Quarter.—From the first quarter, the moon is gradually brought into opposition when the centres of the three bodies are again nearly in a straight line, the earth being the middle body. The whole illumined hemisphere is then exposed to the earth and the moon is full. From this point as she moves onward, she passes through the third quarter, when her appearance is similar to the first, with the curved portion in the opposite direction. From this she gradually wanes and becomes invisible.

Full moon at its greatest altitude in winter—New Moon at its least.—Having considered the altitude of the sun and ecliptic, as the moon's orbit is inclined only at a small angle to the earth's it will always be found near the plane of the ecliptic. Bring the earth to the winter solstice, and the

moon in conjunction; the sun's altitude at midday is then at its minimum. The new moon is nearly in the direction of the sun; as it can never depart more than $5\frac{1}{3}°$ from the ecliptic. Now revolve the moon to the point of opposition; she is full, and in crossing the meridian her altitude is about 47° greater than when new. This illustration as well as others pertaining to the altitude of the moon, is facilitated by the use of the angle measurer and zenith director; these enable the operator to determine with great accuracy the zenith distance, and hence the altitude of the moon.

Full Moon at its least and New Moon at its greatest altitude in summer. — Bring the earth to the summer solstice and the moon in conjunction, she is then near the sun and at her greatest altitude. Revolve the moon to opposition, she is near that part of the ecliptic in which if the sun were, it would have its least altitude; and, therefore, the full moon is low, varying from 21° to 31° above the horizon when on the meridian.

First Quarter low, and third Quarter high at the autumnal equinox.— When the earth is at the autumnal equinox, and the moon in her first quarter and on the meridian, she is at that part of the ecliptic where it diverges most from the earth's axis, she is therefore low. When she passes around to the third quarter her altitude is about 47° greater.

First Quarter high and third Quarter low at the vernal equinox. — A single lunar revolution renders this fact clear. At the equinoxes, there is but little difference in the altitude of the new and full moon. — It will be readily perceived that these variations of altitude of the moon are occasioned by the revolution of the moon; the inclination of the earth's axis; and the daily revolution of the earth.

Only one side of the moon toward the earth.—The cause of the phenomenon is, that the centre of gravity does not coincide with the centre of magnitude, and as the moon is free to change, the heaviest portion gravitates toward the earth. Use the sun again to render clear this fact. As a consequence, the moon revolves upon her axis in the same time she revolves around the earth. In the instrument, it is evident that one side of the moon is constantly toward the earth.

Moon's Librations.—The librations of the moon are of longitude and latitude. Those of longitude are occasioned by the more rapid motion of the moon through its perigee than apogee, its revolution upon its axis being regular. Notice that one face of the moon is toward the point of the moon's attachment; and, also, that the earth may be upon one side or the other of the centre of the wheel rotating the earth; and the moon being viewed from these points presents different hemispheres, sometimes including a little more of the eastern limb, and sometimes a little more of the western than usual. The librations commonly called diurnal are of longitude and are occasioned by the distance of the observer from the centre of the earth. The same surface of the moon is toward the centre of the earth; hence, when the moon is in the eastern horizon more of the western side becomes visible; when she is in the western, more of the eastern can be seen. The two observations are made at a distance apart to correspond to 8000 miles, and the hemispheres brought to view are not exactly the same.

Librations of Latitude.— The axis about which the moon rotates remains in about the same direction in space, but is not quite perpendicular to the plane of the moon's orbit, being inclined from the perpendicular

$1\frac{1}{2}°$; her orbit, too, is inclined to the ecliptic, hence, as the moon revolves about the earth, more of the surface about either the north or the south pole becomes visible. The general principle may be indicated by elevating the moon to its highest point exhibiting a greater amount of lunar surface about its pole.

Recession of the Moon's Nodes. —The plane of the moon's orbit being inclined to the ecliptic and the earth at all times being in both planes, it is evident that the moon in its journey around the earth is half the period of one revolution upon each side of the ecliptic. The points of crossing are called nodes. The centre of the moon at each revolution when at its node, intersects the ecliptic a little westward of its former point causing the phenomenon of the recession of the moon's nodes. A complete circuit of the ecliptic is made by the node in a period of about 18.6 years. A straight mark upon the middle horizontal wheel indicates the line of the nodes. To illustrate this recession, notice that when the moon is in the same direction from the earth as this line that she is at her node. Give motion to the shaft till the line of the nodes extends toward the sun; mark the position of the earth in its orbit; revolve the earth, and observe that the line is directed toward the sun again before a complete annual revolution has been made, or in less than a year. As the moon moves onward her point of crossing the ecliptic falls backward or recedes about one-eighteenth each year so that when 18.2 revolutions have been completed, the node has made an entire circuit, and is again at its starting point.

The nodes are known as the ascending and the descending; the former occurs when the moon crosses to the northern side, and the latter, when she passes to the southern side of the ecliptic.

Effect of the Recession of the Moon's nodes upon the altitude of the full Moon. — The recession of the moon's nodes affects and regulates to the amount of $10\frac{1}{4}°$ the altitude of the full moon; that is, the full moon may take place $5\frac{1}{8}°$ north of the ecliptic, that much south of it, or any where between these limits. If the node months are March and September, then in December, the full moon occurs when she is 90° from her node, and at her greatest distance from the ecliptic. Presume this to be her greatest distance north when her altitude is about $78\frac{5}{8}°$. The corresponding full moon the following year will take place 70° from her node, hence nearer the ecliptic and at a less altitude; the next year 50° from her node, approaching each year until December and June become the node months. The full moon then will have about the same altitude as the ecliptic or $73\frac{1}{2}°$. It continues southward till the node months become again March and September, when her altitude is about $68\frac{3}{8}°$; during the next nine years the change is northward, at the expiration of which time, her maximum altitude is again reached. The full moon in December in (1865) occurs north of the ecliptic, but as the node months are April and October, she will not attain her greatest altitude. The full moons occurring in any other month are similarly affected. The moon in any phase undergoes the same variation of altitude. To illustrate all these phenomena; measure the altitude of each full moon in December for a period corresponding to 18 years, when it will be found, that her position oscillates between two fixed points at a distance apart of $10\frac{1}{4}°$. Determine the same thing of the moon, when she is new; at her first and third quarters; and at any season of the year. If it is desired to commence the

measurement when the full moon is at her greatest altitude, it will be necessary to revolve the instrument till the line of the nodes becomes at right angles to the main shaft in December, and the moon's plane inclines toward it.

Tides.—A band of paper with two widened portions may be placed on the earth extending around its central portion so that it may be moved at pleasure. Bring the earth to either equinox and the moon either to conjunction or opposition. Spring tides occur under these circumstances, and the greatest elevation of water is around the equatorial regions under the sun and moon. The enlarged portions represent the high water and they can be retained under the moon as she revolves showing that the tide follows the moon. One fourth of a lunar revolution shows the position of the earth and sun to produce neap tides. When the earth is at either solstice, extend the paper diagonally across its surface, to show that the spring tides are highest 23½° north of the equator, and on the opposite side of the earth as far south of the equator; observe then, as the earth revolves upon its axis that each alternate tide is higher. The paper may be varied to correspond to the different positions of the earth and moon in such a manner as to give a general idea of the tides and their positions

CHAPTER III.

ECLIPSES.

The phenomena of solar and lunar eclipses are among the most conspicious exhibited by the Geoselenean. They appear to the best advantage in a dark room when a strong light is used. The experiment is marred somewhat by the use of so small a luminous body for the sun which produces diverging instead of converging shadows of the moon and earth. The disability may be partly overcome by the use of a lamp with several burners, or of a concave mirror.

Lunar Eclipse. — A lunar eclipse occurs when the moon is in opposition. To illustrate an eclipse of the moon; observe that when the moon is full and at her node she falls into the earth's shadow in her passage through the point of opposition; and she is eclipsed for a longer time under these circumstances than any other because she passes through the central portion of the shadow. A lunar eclipse will occur when the moon is some degrees from her node, but it will be of shorter duration. Notice also, that the moon both in entering the earth's shadow and departing from it is partially eclipsed and that the figure of the earth's shadow is circular—a fact frequently adduced to illustrate the rotundity of the earth. The moon does not suffer an eclipse at every revolution, because her orbit is inclined to the ecliptic and she may in passing the point of opposition be either below or above the earth's shadow.

Solar Eclipse.—An eclipse of the sun is occasioned by the interposition of the body of the moon intercepting a part or the whole of the sunlight. It can only take place at the dark of the moon and may be thus illustrated: revolve the moon to conjunction, when if she is at or near her node she eclipses the sun. The shadow of the moon is projected distinctly upon the earth and passes over its equinoctial regions when the moon is exactly at her node, if she is some distance from it, the eclipse will be observed farther north or south, and the northern or southern limb of the sun will be obscured. As the moon's orbit is inclined, she may be when in conjunction sufficiently far above or below the straight line joining the cen-

tres of the earth and sun that her shadow would be cast either over or under the earth causing no eclipse of the sun.

It will readily be perceived that if the orbit of the moon coincided with the orbit of the earth, at every revolution of the moon, there would be both a solar and lunar eclipse.

All eclipses are not visible in the United States. — From the above illustrations, it was doubtless observed, that during a solar eclipse, the moon's shadow was projected upon different portions of the earth; as, Asia, Africa, and South America, etc. Also during a lunar eclipse other portions of the earth than ours are turned toward the moon. Eclipses of the sun and moon which happen when these bodies are below our horizon are invisible to us.

An Eclipse of the Sun and Moon about 15 *days apart.* — Upon the consultation of an almanac, it is found that this year (1865) there was an eclipse of the moon on the 10th and one of the sun on the 25th of April. Although this usually happens, yet it is not universal. An eclipse of the sun may occur when the moon is any distance from her node not exceeding 17°; and one of the moon when she is within 12°. While the earth moves through these 29° of its orbit, which requires about 29 days, the moon crosses the ecliptic twice or every 15 days; and is sufficiently near her node to cause both a solar and lunar eclipse. Should an eclipse of the sun occur, just when the moon is at her node, half a lunar revolution would bring the moon beyond her ecliptic limit, so that she would not be eclipsed. This becomes apparent by observing when the line of the nodes is directed nearly toward the sun, the moon being in conjunction; it may be revolved to opposition before the line becomes materially changed.

Two Solar Eclipses about 6 *Months apart.* — The two eclipses of the sun in 1865 are April 25th and October 19th. Mark the month that the line of the nodes is directed toward the sun; revolve the earth till this line again becomes coincident with the main shaft, which will be in a little less than six months. Then, when the moon is in conjunction she is sufficiently near her nodes to eclipse the sun. The time between lunar eclipses is also usually about six months.

Frequency of Eclipses.—It is seen from the above that four is the usual number of eclipses in a year, but there may be more. Revolve the instrument till the line of the nodes is coincident with the main shaft about the first of January, as it is again directed toward the sun in a little less than six months, the node months become June and December causing in one year three periods of eclipses.

Effect of the Recession of the Moon's nodes upon Eclipses. — Bring the moon into conjunction and at her node; revolve the earth till the line of the nodes is again toward the sun which will be a period corresponding to 346.62 days. An eclipse will not occur at this place because the moon will not be in conjunction; as the 346.62 days, a synodic revolution of the moons nodes, are not measured by 29.53 days a synodic revolution of the moon. There are 12 new moons in about 10 days less than a year; hence, the moon may be sufficiently near the node to eclipse the sun when she reaches her twelfth conjunction, which will cause the eclipses to take place about 10 days earlier each year.

In 223 lunations which require about 18 years and 10 days, there are about 19 synodic revolutions of the moon's nodes. It results from this,

that the sun, earth, and moon occupy the same relative positions every 18 years and 10 days. The 70 eclipses which happen in this period will take place in the same manner and order every cycle for ages to come. These eclipses will be visible from places about the same latitude but not the same longitude. In 1846 there were two eclipses of the sun, April 25th and October 19th; in 1864 there were also two, May 5th and October 30th; in 1847 eclipses occurred April 15th and October 9th; in 1865, April 25th and October 19th. Continue the revolutions till the line of the nodes has made a circuit of the ecliptic which will require a period corresponding to 18.2 years. The cycle of eclipses is then complete and a further revolution will repeat the eclipses in the same order.

The Geoselenean shows more than the real number of eclipses, especially of the moon, and also more of the moon than the sun, when there is a less number. This is occasioned by the diverging shadow of the earth. It will not be difficult, however, to understand why there is a greater number of solar than lunar eclipses. Two tangent lines extending from the sun touching the earth converge to a point. At the moon's distance from the earth when in opposition, these lines are about 6,000 miles apart. when she is in conjunction, they are about 10,000 miles apart. Eclipses happen when the moon is partially or entirely within these lines; one half of these spaces represents the distance the moon should be from the ecliptic to prevent an eclipse; if then she is sufficiently far from her node to be more than 3,000 miles and less than 5,000 miles, there may be an eclipse of the sun but not of the moon. Of the 70 eclipses of the Saros 41 are of the sun, and 29 of the moon.

CHAPTER IV.

THE SUN AND THE PLANETS

The sun occupies the central portion of the apparatus and is free to revolve; its motion upon its axis may be shown by a hand movement, and the difference between its synodic and sidereal revolution illustrated. The sun's axis is inclined to the ecliptic at an angle of of 82¾° and toward that portion of it which the earth occupies in March.

Direction of the Solar Spots.—To represent the solar spots, place upon the sun's surface about its equinoctial regions, small circular pieces of paper and revolve the sun upon its axis. During March as the sun's axis is inclined toward that part of the ecliptic, the spots will appear to describe a curve bulging downward. As the earth revolves, the curvature diminishes until the summer solstice is reached when the spots seem to cross in a straight line inclining upward. In September, they will appear again most curved, and as the sun's axis is most inclined from this point the oval part will be upward. In December, their direction is again straight but inclining downward.

The Planets.—To illustrate the phenomena of the planets, it is necessary to place instead of the earth's elbow those corresponding to the inclination of the axes of the different planets; and to use the plain balls. The main shaft may or may not, at the pleasure of the operator, be inclined till the axis of the planet will be directed toward the zenith. It may be stated, generally, *that any phenomena which can be shown of the earth and its moon, may be illustrated of all the planets and their satellites.* It will, therefore only be essential, to indicate how the Geoselenean may be used to elucidate those phenomena which differ materially from the earth's,

leaving the experimenter to follow a course in other cases similar to that pursued in the foregoing illustrations.

To render clearer the relative positions of the planets, an extra shaft has been prepared to put temporarily upon the sun's axis. In illustration of the exterior planets, the earth may be placed upon this shaft; of the interior planets, they may sometimes occupy this position.

Venus and Mars. — The axis of Venus is inclined to the plane of its orbit at an angle of 15°. Use the elbow with the obtuse angle; place the planet upon its axis, and give motion to the apparatus, it will be observed how the sun can be vertical within 15° of the poles and how the great obliquity produces the inequality of the seasons. As Venus has no satellite the earth's can be detached. The phases of the planet, and its elongations also become apparent, as the point of our observation is at a greater distance from the sun than the planet. For the axis of Mars, the earth's may be used, his phenomena are very similar to the earth's, he has no satellite.

Jupiter.—Jupiter's axis is nearly perpendicular to his orbit; place on the elbow which forms nearly a right angle, and in the small apertures beneath the wheel giving the diurnal rotation to the planets, insert the three additional satellites, for his fourth use the earth's. Observe in a revolution of Jupiter that the sun's rays fall vertically always at or near his equator; and that his seasons though longer than those of the earth undergo but little change. His satellites are at about their relative distances, but they do not all revolve in the same time as the Geoselenean indicates. Three of them move around his equatorial regions and suffer an eclipse at every revolution; this is true to nature, and is caused by their orbits being nearly coincident with that of the planet. The fourth moon is farther away and its orbit is more inclined, it may, therefore, pass the point of opposition without being eclipsed. These satellites except the fourth, eclipse the sun at every revolution and their shadows may be observed crossing the disk of the planet.

Saturn.—For Saturn a ball has been specially prepared with rings encircling his equatorial regions and with seven satellites attached, the earth's being designed as the eighth. His axis is inclined to his orbit 63°. rendering his seasons not much unlike those of the earth except in length. When Saturn is at his equinoctial points, the plane of the rings extends through the sun and as only the edge is then illuminated they are invisible to us. They also vanish when their edge is toward the earth or their illuminated side is turned from the earth. At the solstitial points, the rings are more inclined to the direction of observation, and are most favorable for being viewed. By a single revolution, the various positions of the rings become apparent. Seven of his satellites revolve in orbits nearly coincident with the plane of the rings, and hence are eclipsed at each revolution near the equinoxes, the eighth moves in an orbit more inclined and sometimes escapes. When the planet is near its solstitial point, the inclination of the satellites, places them either above or below the planet's shadow so that they are but seldom eclipsed while the planet is pursuing these portions of its journey.

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